# A TURBO PASCAL IMPLEMENTATION OF AN EXTENDED MATERIAL REQUIREMENTS PLANNING SYSTEM

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*by*


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*to the*


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Dedicated

to

My Mother

# CERTIFICATE

Certified that the work on "A Turbo Pascal Implementation of an Extended Material Requirements Planning System", by Mr. S. V. Ravi Kumar, has been carried out under my supervision and has not been submitted elsewhere for a degree.

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## ABSTRACT

The Material Requirements Planning ( MRP ) has undergone considerable amount of development since its inception in the early 60's. Various lot sizing policies were developed to operate in the discrete demand environment of an MRP system. Nowadays, extended MRP systems are becoming popular since they link MRP to financial planning. Financial planning is useful in generating managerial reports on the projections of future expenses, revenues, inventory levels etc., which in tern help in projecting the future cash requirements, funds flow, balance sheets, profitability measures etc. In the present work, an extended MRP system is designed and implemented in Turbo Pascal Version 3.0. Various lot sizing policies are implemented. Further, various provisions for selecting single-level optimal lot sizing policy. Regenerative method is used to replan the system. Further, the system generates financial reports on projections of future inventory levels, cash requirements and sales revenues. The extended MRP software packages developed in this work can support a product structure of upto 26 levels and 17576 items.

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# CHAPTER I

# INTRODUCTION

## 1.1 Material Requirements Planning :

Material Requirements Planning (MRP) is a computer based production planning and inventory control system. An MRP system is defined as a set of logically related procedures, decision rules and records designed to translate a Master Production Schedule (MPS) into time-phased net requirements and the planned coverage of such requirements for each component inventory item needed to implement this schedule [ 9 ]. The MPS outlines the time-phased production plan for all the end items. The key features of an MRP system are the time-phasing of requirements, generation of lower level requirements, planned order releases and rescheduling capability.

The objectives of an MRP system are as follows:

1. Plan manufacturing activities, delivery schedules and purchase schedules so as to ensure the availability of materials, components and end products for customer delivery.
2. Reduce inventory investment.
3. Improve plant operation efficiency.

There is a basic difference in the applicability of traditional inventory control methods (order point systems) and the MRP. The MRP systems are appropriate for dependent environment items where as order point systems are appropriate

for independent demand environment. For order point systems, future demand is forecast based on the past history of demand. These forecasts are used to replenish the stock levels. In MRP systems, past demand for component parts is irrelevant. The ordering philosophy is based on requirements generated from the MPS. MRP is future-oriented; it derives the future demand for component parts from higher-level demand forecasts. Another distinction is the requirements philosophy used in MRP systems versus the replenishment philosophy used in order-point systems. A replenishment philosophy indicates that material should be replenished when it runs low. An MRP system does not do this. More material is ordered only when a need exists as directed by the MPS. If there are no manufacturing requirements for a particular part, it will not be replenished, even though the inventory level is low. This requirements concept is particularly important in manufacturing because demand for the component parts is 'lumpy'.

The objective in managing independent demand inventories with reorder point rules is to provide a higher customer service level at low inventory operating costs. This objective is oriented toward the customer. On the otherhand, the objective in managing the dependent demand inventories with MRP is to support the mater production schedule. Thus in MRP the objective is manufacturing-oriented [ 10 ].

## 1.2 Past and Present Works :

The origin of MRP took place in the early 60's. Joseph Orlicky was the main contributor to the development of MRP from

its early stages. Oliver Wight and George Plossl have contributed a lot to the growth of MRP in its later stages.

MRP went through four basic stages in its evolution [ 13 ]. Early MRP systems were very crude, usually operating in monthly time periods and recalculated once after every month. But all these MRP systems were limited in that they simply launched the orders.

In the second stage, it evolved into a "priority planning system". These systems have rescheduling capability. The notion that material already on order should be reviewed to see if it needed to be moved into an earlier or a later time period was the beginning of MRP's developing into a scheduling system. The idea of getting feedback on what was really happening and keeping the MPS up to date made MRP a true priority planning system.

Then in the late 1970's Oliver Wight, George Plossl and others began to talk about closing the loop in MRP systems. Thus the evolved into third stage. The closed loop MRP systems is a system built around material requirements planning and also including the additional planning functions of production planning (aggregate planning), master production scheduling and capacity requirements planning. Further, once the planning phase is complete and the plans have been accepted as realistic and attainable, the execution functions come into play. These include the shop floor control functions of input-output measurement, detailed scheduling and dispatching, plus anticipated delay reports from both the shop and vendors, purchasing follow-up and control, etc. The term "closed loop" implies that not only are

these elements included in the overall system but also that there is feedback from the execution functions so that the planning can be kept valid at all times [ 12 ].

Then, it evolved into MRP II: Manufacturing Resource Planning. Here also the main contributors were Wight and Plossl. The term manufacturing resource planning is a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in rupees, and has a simulation capability to answer "what-if" questions. It is made up of a variety of functions, each linked together:business planning, production planning, master production scheduling, material requirements planning, capacity requirements planning, and even the execution support systems for capacity and material. Output from these systems would be integrated with financial reports such as business plan, purchase commitment report, shipping budget inventory projections in rupees etc. Manufacturing Resource Planning is a direct outgrowth and extension of closed loop MRP system [ 12 ]. The most significant development in the evolution of MRP II was that it became a company game plan: a way to plan and control all the resources of a manufacturing company - a common plan that marketing, manufacturing, finance and engineering could use to work together.

In any MRP system, the specification of MPS and the acceptance of order-action plans require negotiation and compromise among marketing, production, purchasing and financial interests. For this purpose, an MRP system should communicate

information in a language that is common to all the participants. Hershauer and Eck [ 10 ] suggested that the appropriate language is financial in nature; that is the proposed master production schedules and derived material requirements plans should be evaluated, atleast in part, by projecting the future balance sheets, income statements, cash requirements, funds flow, profitability measures and so forth, that can be anticipated if an MPS and the MRP plans are implemented. Thus, the main emphasis in MRP II is on financial planning systems. These systems are useful in three ways.

1. To initiate a series of what-if analyses.
2. To provide data needed for an adequate cost control and even to facilitate the pricing of the items.
3. To establish a link to Capacity Requirements Planning (in financial terms) so as to make the system a closed-loop MRP system.

Since MRP systems require massive data processing at high speed, its growth has paralleled developments in the computer field. The origin of MRP, around 1960, was in line with the movement toward acceptance of quantitative management tools that used the fast data processing capability of computers. Lot of software packages have been developed for MRP systems implementation. Since the implementation of MRP has become easier, because of computers, lot of companies have started using MRP systems. With the advent of micro computers and personal computers, now there is tremendous rise in the number of MRP system installations.

J. H. Blackstone Jr. and James F. Cox [ 3 ] have

conducted survey of the software packages available for MRP systems. Burroughs, Honeywell, Anacomp etc. are some of the vendors of the mini computer implementations of the MRP systems. Some of the vendors of micro computer versions of MRP are Twin Oaks, Micro MRP Inc., Professional Integration etc. Many of these packages seem to have restriction on the number of items and the number of bill of material levels. Earlier MRP software packages were purely production planning programs and lacked CRP, financial planning, shop-floor control and replanning capabilities. In the MRP software developed in this work, we have concentrated on the implementation of various lot sizing methods with provision for the selection of single-level optimal lot sizing policy. Further, financial planning concepts are also incorporated.

## 1.3 Organization of the Thesis :

Chapter II discusses the concepts of the MRP systems i.e. MRP logic, lot sizing policies, extended MRP systems, replanning of the system, "nervousness" in MRP etc.

Chapter III discusses the system implementation details like features of MRP that are implemented, organization of databases, coding system employed, limitations of the system etc.

Chapter IV presents the results obtained from a trial run of the system. Scope for further work is also given in this chapter.

User's manual is given in chapter V.

# CHAPTER II

# CONCEPTS OF MRP

This chapter discusses the various features of MRP like parts-explosion process, lot sizing methods, features of extended MRP systems, system replanning etc.

## 2.1 Prerequisites and Assumptions :

The following are the prerequisites and the assumptions of an MRP system.

1. Existence of a master production schedule.

2. Each inventory item must be unambiguously identified through a unique code (part number).

3. Availability of inventory records for all items under the system's control.

4. For system's effective operation, file data integrity pertaining to inventory status data and the bill of material (BOM) data, is needed. Though an MRP system can function even with faulty data, file data must be accurate, complete and upto date, if the MRP system is to prove successful and even useful.

5. Lead times for all inventory items are known and can be supplied to the system.

6. All the components of an assembly are needed at the time of assembly order release.

7. Disbursement and usage of materials is assumed to be discrete.

8. Process dependencies ( eg. set-up dependencies ) are not

considered.)

## 2.2 MRP Elements :

The primary outputs of an MRP system are as follows.

1. Order release notices, calling for the placement of planned orders.

2. List of planned orders scheduled for release in the future.

3. Rescheduling notices, calling for the changes in the open order due dates.

4. Item status analyses.

5. Reports on projected expenses (manufacturing, purchasing, inventory carrying costs etc.) and revenues (from sales).

6. All the information necessary for the development of a closed-loop MRP through Capacity Requirements Planning (CRP).

There are a number of inputs required for the MRP system to generate the above outputs. The main input that drives the entire MRP system is the master production schedule. It is accepted as given. The inventory status file and the bills of material file supply additional information about the products included in the master production schedule. These inputs are fed into the MRP computer program, which generate the outputs. The inventory transactions resulting from MRP actions are put back into the inventory status file so that current inventory records are maintained. The various elements of an MRP system that are needed to generate the above outputs are discussed below.

**2.2.1 Master Production Schedule (MPS) :** This is the time-phased production schedule of the forecast demand for all the end

items. This serves as the the main input to an MRP system, in the sense that the essential purpose of the system is to translate the MPS into individual component requirements and other inputs merely supply reference data that are required to achieve this objective.

The parts explosion process of an MRP system assumes that the MPS is feasible with respect to capacity. An MPS begins as a trail schedule, to be tested for feasibility through MRP and a process called Capacity Requirements Planning (CRP). Using the master production schedule as input, parts are exploded to produce shop orders and purchase orders. These orders are put into CRP routine to determine whether sufficient capacity is available. If the requirements can not be met by the material available from the inventory, material on order, or if sufficient capacity is not available, then either capacity or the MPS must be modified until the MPS is feasible. Another function of mater scheduling is to make sure that the final master schedule is not inflated and reflected realistic capacity constraints.

The master schedule is often developed in terms of periodic output requirements or so called time-buckets. The early periods of the MPS are understood to be frozen, the middle periods are described as firm, and the later periods are said to be free or open. The early periods are frozen so that production departments can depend on this portion of the plan to the extent that material can be ordered, personnel can be scheduled to work and machine change-overs can be scheduled to support the MPS. After one period, the MPS is updated by dropping off period 1,

since period 1 would then be history, and adding a period onto the end of the schedule. This rolling schedule nature of the MPS must, however, observe the frozen character of the early periods of the old MPS to allow for rational and systematic acquisition of material flows to support the schedule, which is an absolute must in MRP [ 5 ].

Rarely, MPS is a reflection of future demand forecasts. Rather the MPS is a forecast of what will be produced. It is a 'build' schedule. Finished goods inventory is a buffer between the MPS and final customer demand, smoothing out work loads and providing fast customer service.

**2.2.2 Independent Demand for Component Items :** This include service-part requirements, inter-plant requirements etc. This demand is either forecast or recorded upon the receipt of orders. The MRP system treats this category as additions to the gross requirements (calculated as the dependent demand) for the respective component requirements.

**2.2.3 Product Structure :** This is a structured list of all the materials or parts needed to produce a particular finished product, assembly, sub-assembly, manufactured part or purchased part. This gives the information regarding the relationship between components and assemblies i.e. which component/sub-assembly goes where information. This is also called Bill of Material (BOM). The format used here for the representation of BOM is called the single-level implosion format. This format is that of a where-used list. The BOM is stored as a table showing the list of all the parents (on the immediate higher level only)

for each item.

The BOMs should be 100 percent accurate. If there are errors in the BOM, the proper materials in proper quantities will not be ordered and the product can not be assembled and shipped. BOMs are constantly undergoing change as products are redesigned. Thus an effective engineering-change-order (ECO) system is needed to keep the BOMs up to date.

**2.2.4 Inventory Status File :** This is also called item master file. This contains individual item inventory records containing the status data required for the determination of the requirements, such as part code, lead time, cost data, on hand inventory etc. This file is kept up to date by posting of inventory transactions.

**2.2.5 Planning Horizon :** The time span which, the MPS covers is called the planning horizon. As a general rule, planning horizon shorter than the cumulative lead time for the end items is inadequate. The cumulative lead time is the shortest time in which the end item can be made. Very little planning can be done at lower levels of components, if a planning horizon shorter than the cumulative lead time is adopted. On the otherhand, too long a planning horizon necessitates larger amounts of data processing. Furthermore, the longer the planning horizon, the less reliable becomes the data about demand forecasting [ 1 ].

**2.2.6 Capacity Planning :** The MRP system assumes that the MPS can be executed within the production capacity constraints. If sufficient capacity is not available, inventories will rise, past

due orders will build up and expediting will be used to pull orders through the factory. To correct this situation, a capacity planning subsystem is needed.

The purpose of capacity planning is to check on the feasibility of the MPS. There are two ways this can be done: rough-cut capacity planning (also called resource planning) and shop loading. In rough-cut capacity planning, approximate labour hours and machine hours are calculated directly from the MPS to project future capacity needs without going through the parts-explosion process. When sufficient capacity is not available, the MPS is adjusted or capacity is changed to obtain a feasible schedule. When the MPS is feasible, then the full parts explosion is run.

When shop loading is used, a full parts explosion is run prior to capacity planning. The resulting shop orders are then loaded against work centers through the use of detailed parts-routing data. As a result, work force and machine hours for each work center are projected into the future. If sufficient capacity is not available, either capacity or the MPS should be adjusted until the MPS is feasible. At this point, a valid material plan is available.

**2.2.7 Purchasing :** The purchasing function is greatly enhanced by the use of an MRP system. First, past-due orders are largely eliminated because MRP generates valid due dates and keeps them up to date. By developing and executing a valid material plan, management can eliminate much of the order expediting which is usually done by purchasing. With an MRP system, it is possible to

provide the vendors with reports of planned future orders. This gives vendors time to plan capacity before actual orders are placed.

## 2.3. MRP Processing :

**2.3.1 Gross Requirements :** This is the quantity of the item that will have to be issued to support a parent order. An end item is subjected to only independent demand and hence the MPS will give the gross requirements for that item. Any other item may be subjected to dependent demand from one or several parent items that use it in common, and it may also be subjected to independent demand generating from sources external to the plant. The gross requirement for this item will be the sum of dependent demand from all its parents and the independent demand.

**2.3.2 Scheduled Receipts :** These represent the material on order scheduled to arrive in the future periods.

**2.3.3 Net Requirements :** Net requirements are developed by allocating quantities in inventory to the quantities of gross requirements, in a level-by-level process.

Net requirement = Gross requirement - Scheduled receipt - on hand quantity

If the result obtained by the above formula is negative, the net requirement is zero.

**2.3.4 Safety Stock :** This is a part of stock replenishment concept and as such should not be incorporated into an MRP system. But some MRP users argue that safety stock performs the

same function in MRP systems as in other inventory planning systems avoiding excessive stockouts caused by uncertain lead times and daily demands. Those who oppose the use of safety stock in MRP argue that because MRP systems adapt to changing conditions that affect demand and lead times, safety stock will not actually be used under the vast majority of circumstances in MRP.

The use of safety stock can be justified only by the source of uncertainty present during lead times. For higher-level items and the components that are used as service parts, the uncertainty of demand compares with any other inventory item having independent demand. The uncertainty of lead times for these items seems more controllable if these items are produced in-house. On balance, the use of safety stock for end items in MRP systems can be justified on the basis as in any other system-the presence of uncertain demand and uncertain lead times.

For lower-level items such as raw materials and parts, the uncertainty of demand is adequately controlled because the demand is dependent demand. The MPS sets the periodic demand for these items. The only major uncertainties present during lead times are the uncertainty of lead time and the uncertainty of demand that occurs because of changes in the MPS. It appears that some safety stock can certainly be justified, even in raw materials, parts, and other lower-level items, although at significantly reduced levels. For the items for which safety stock is to be provided, the desired safety stock quantity has to be subtracted from the on-hand quantity before computing the net

requirements.

2.3.5 **Allocated Quantity** : The quantity allocated indicates the quantity of the item earmarked for a parent order that has been released but for which the material requisition has not yet been filled. This allocated quantity has to be subtracted from the on-hand amount before computing the net requirements.

2.3.6. **Coverage of Net Requirements**: In an MRP system, the net requirements are to be covered by planned orders i.e. new orders for the respective item scheduled for release in the future. To generate a planned order, the system must determine the following.

1. The order quantity.
2. The timing of the required order completion (due date).
3. The timing of order release.

The first two tasks are accomplished by lot sizing and the third one by time phasing.

2.3.7. **Lot sizing**: In material requirements planning, whenever there is a net requirement for a material, a decision must be made concerning how much of the material to order. These decisions are commonly called lot sizing decisions. In produce-to-stock firms, the size of production lots is primarily a question of economics. Lot sizes have to be large because of the following reasons:

1. The cost of changing over machines between production lots in the course of the year is less and production capacity is greater because of less downtime caused by machine changeovers.

2. The cost of placing a purchase order is less in the course of a year because only a few orders for large lots of materials are placed with suppliers.

3. By ordering large lots of materials from suppliers, price breaks and transportation cost breaks can be taken advantage of, resulting in lower purchasing costs of the materials.

But smaller lot sizes are advantageous because of the following reasons:

1. Smaller lot sizes result in lower average inventory levels and the annual cost of carrying inventories is less.

2. Lower inventory levels can reduce the risk of obsolescence when product designs are changed.

Therefore, operations managers have to strike a balance between lots that are not too large and lots that are not too small. The MRP system operates in a discrete demand environment and the net requirements for materials have been described as lumpy demand (which means that the demand varies greatly from one period to another). With this point in mind, a number of lot sizing methods were developed [ 9 ] apart from the optimal procedure by Wagner-Whitin algorithm [ 11 ]. They are discussed below.

2.3.7.1 Lot for Lot (LFL) : This provides period-by-period coverage of net requirements, and the planned order quantity always equals the net requirement of the corresponding period. The use of this technique minimizes inventory carrying cost. It is often used for expensive purchased items, and for any items, purchased or manufactured, that have highly discontinuous demand.

That is, items in high volume production and items that pass through specialized facilities geared to continuous production (equivalent to permanent setup) are normally ordered lot for lot. Table 2.1 provides an example of this method of ordering.

**2.3.7.2 Fixed Order Quantity (FOQ) :** The order size. equals an integer multiple of a specified quantity. This is used where the item has to be purchased/manufactured in certain fixed quantity only. This policy would be applicable to items with ordering cost sufficiently high to rule out ordering in net requirement quantities, period by period. Table 2.2 provides an example of this method of ordering.

**2.3.7.3 Minimum Order Quantity (MOQ) :** In this approach, whenever an order is launched, it has to be greater than or equal to a specified minimum quantity. This method is illustrated in Table 2.3.

**2.3.7.4 EOQ :** The concept of EOQ can be incorporated into the MRP system. The value of EOQ is to be computed first and then the orders are to be planned with EOQ as the minimum quantity to be ordered. The EOQ is based on an assumption of continuous, steady-rate demand, and it will perform well only where the actual demand approximates this assumption. But the demand in MRP is both discontinuous and nonuniform. The more discontinuous and nonuniform the demand, the less effective the EOQ will prove to be. Table 2.4 illustrates this method of ordering with the above data.

Setup cost = Rs.100 Carrying cost = Rs. 1 /unit/period

2.3.7.5 Modified EOQ : This method was developed by Amitava Mitra et. al. [ 8 ]. At an order point, the order quantity is determined as follows. The EOQ is computed and rounded to an integer value. Net requirements are accumulated until it exceeds EOQ. Let period 'n' be the period in which this occurs first. Let the ordering point, the period in which we are trying to determine the order quantity, be denoted by 'm'.

Let $Q_1 = \sum_{i=m}^{n} d_i$ where $Q_1$ exceeds EOQ

$Q_2 = \sum_{i=m}^{n-1} d_i$ where $Q_2$ is less than EOQ

and $d_i$ denotes net requirement in the period i. Then the order quantity is $Q_1$ or $Q_2$ , whichever is closer to EOQ. If EOQ is exactly half-way between $Q_1$ and $Q_2$ , then the order quantity is chosen to be $Q_2$ . This method is illustrated in Table 4.5.

2.3.7.6 Fixed Period Requirements (FPR) : In this approach, the total of net requirements of a specified fixed number of periods is to be ordered at every ordering point. In fixed order quantity approach, the ordering quantity is constant and the ordering intervals vary, while in fixed period requirements approach, the ordering interval is constant (except when there is a zero requirement in a given period, which will extend the ordering interval) and the quantities are allowed to vary. This method is illustrated in Table 2.6.

2.3.7.7 Period Order Quantity (POQ) : This approach is based on

the logic of EOQ, modified for use in an environment of discrete period demand. EOQ is first computed to determine the number of orders per year that should be placed. Then the number of planning periods is divided by this quantity to determine ordering interval. The POQ technique is identical to FPR except that the ordering interval is computed. Since this is a fixed interval technique, it avoids 'remnants' in an effort to reduce the inventory carrying cost. For this reason, POQ is more effective than the EOQ, as setup cost per year is the same but carrying cost will tend to be lower under POQ. This method is illustrated in Table 2.7 with the following data.

EOQ = 58

Number of periods in year = 12

Ordering interval = 58*12/200 = 3.5 = 4

**2.3.7.8 Least Unit Cost (LUC)** : In this approach, in determining the order quantity, the LUC technique asks whether this quantity should equal the first period's net requirement or whether it should be increased to cover the next period's requirement also, or the one after that also etc. The decision is based on the unit cost (i.e. set-up and inventory carrying cost per unit) computed for each of the successive order quantities. The one with the least unit cost is chosen to be the order quantity. This method is illustrated in Table 2.8 with the same data as given in section 2.3.7.4.

**2.3.7.9 Least Total Cost (LTC)** : This approach is based on the rationale that the sum of set-up and inventory costs are as

nearly equal as possible. This is achieved through the computation of the so called economic part-period factor or EPP. The EPP is defined as the quantity of the inventory item which if carried in inventory for one period would result in a carrying cost equal to the set-up cost. It is computed by the formula given below.

$$EPP = S / I$$

where S = set-up cost

I = inventory carrying cost/unit/period

The LTC technique selects the order quantity at which the part-period cost most nearly equals the EPP. This method is illustrated in Table 2.9 with the same data as given in section 2.3.7.4.

The LTC approach is generally favored over the LUC, but its logic has a flaw of its own in the premise that "the least total cost is at the point where the inventory carrying cost and setup cost are equal". This holds good only in the case of EOQ but not in discrete lot sizing approach.

**2.3.7.10. Modified LTC:** This lot sizing method was developed by Mitra et. al. [ 8 ]. In this approach, the EPP and part-periods are computed as usual. The order point (m) and the order quantity are determined using the above mentioned LTC procedure. Let the net requirement in the period 'm' be $d_m$. The modification is that, if the condition

$$d_{m+1} > EPP$$

is satisfied then an order is placed in period 'm' for that period only (i.e. the order quantity is $d_m$ ). Table 2.10 provides an example of this method of ordering, with the following data.

Setup cost = Rs. 100

Carrying cost = Rs. 2 /unit/period

Hence EPP = 100/2 = 50

**2.3.7.11 Wagner-Whitin Algorithm :** Wagner-Whitin algorithm is based on dynamic programming approach and is an optimizing procedure that finds the minimum cost ordering policy [ 11 ]. However, this method is difficult to understand, is very expensive to process on computers, and may not exhibit good cost performance when many changes to net requirements occur every period.

There is another drawback with Wagner-Whitin algorithm. Many real world problems differ in two important respects from the problem modeled by Wagner and Whitin. First, the Wagner-Whitin algorithm guarantees optimal ordering or production lot sizes only for each level of the hierarchy of product structure treated independently. But of course the levels of the product structure are not independent. The essence of an MRP system is to exploit the dependence among levels in projecting future requirements. The second way in which the real world differs from the model involves the use of updated information in rescheduling. The model assumes that demand data remains unchanged during the planning horizon. Because of the above reasons, this lot sizing method is being used rarely.

### 2.3.8 Critique on Lot Sizing Approaches :

One potential problem is said to exist, when lot sizing techniques are applied at every level in this product structure. Norman Gaither [ 5 ] has discussed about the views of some MRP users regarding the use of lot sizing. Using lot sizing in lower level components, some MRP users believe that excessive inventory build ups in lower level components can result. Some MRP users argue, however, that excessive inventory levels are not reached. The per unit cost of lower level components leads to higher lot sizes and consequently higher inventory levels. These MRP users content that higher inventory levels of lower level components should not be surprising or disturbing; the economic lot sizing of all levels of components is therefore recommended.

The tendency in practice is to use Lot-for-Lot (LFL) at all levels for produce-to-order firms. Also, LFL is used in produce-to-stock firms for end items and assemblies and minimum order quantity lot sizes are used for lower level components. The use of LFL in end items and assemblies avoids the inventory build-ups in lower level components described above.

### 2.3.9 Time Phasing :

The planned order releases are computed from the planned order coverage by offsetting for the lead time i.e. by subtracting the value of the lead time from the order completion time. This process is called time phasing.

Sometimes discrepancies or misalignments between net requirements and coverage will arise due to unplanned events or increase in gross requirements. To solve this problem, the timing

of an open order and both the quantity and timing of a planned order can only be changed. Thus to change the gross requirements for a given item, the planned order schedule of its parent item must be changed. After changing, that planned order must be "freezed" so as to prevent the system from changing the planned order back to its value during the next replanning cycle (system replanning is discussed in section 2.6). This is accomplished by what is known as firm planned order. This term denotes the capability by the system to accept a command to "freeze" the quantity and/or timing of a planned order release. The firm planned order command command immobilizes the order in the schedule and forbids the MRP system to put another planned order into the "frozen" period, while replanning.

### 2.3.10 Explosion of Requirements :

The explosion of the requirements from the MPS down into the various component material levels, is guided by the inventory records. Gross requirements for higher-level items are processed against inventory to determine net-requirements, which are then covered by planned orders using lot-sizing. The planned order releases are determined by time-phasing process. The quantity and timing of planned order releases determine, in turn, the quantity and timing of component gross requirements. This procedure is repetitively carried out for the items on successively lower levels until a purchased item is reached. The requirements planning process stops when all the explosion paths that follow the branches of the BOM have reached purchased items.

There will be recurrence of requirements for a given item if

it has more than one parent. Hence, an item record has to be processed only after all its parent records are processed. This is achieved by using the so called low-level coding. The actual coding system is discussed in the section 3.3.

## 2.4 Operating an MRP System :

There is much more to MRP system than just installing the proper computer modules. The management must operate the system in an intelligent and effective way. There has to be an efficient shop floor control. The purpose of shop floor control is to release orders on their way through the factory to make sure that they are completed on time. The shop floor control system helps the management adjust to all the day to day things which go wrong in manufacturing; absenteeism among workers, machine breakdowns, loss of materials and so on. When unplanned complications arise, decisions must be made about what to do next. Good decisions require input-output control and information on job priorities from the shop floor control system. The purpose of input-output control is to ensure that materials are available and that the factory is not overloaded. For each work center, the amount of work put into the work center on a daily or weekly basis is compared to the amount of work produced by the work center (usually measured in standard labor hours or standard machine hours). Furthermore, the material availability of each job is monitored by the shop-floor control system to ensure that both capacity and material are available as the job progresses through the shop. To do its job properly, a shop floor control system requires feedback reports on all jobs as they are

processed. Typically a worker notifies the system as each processing step is completed. This may be done through a computer terminal on the shop floor or by the information submitted to a central office. The computer system then produces a dispatching list for each supervisor each day. This list shows the priority of each job in the work center.

Financial planning and control are the derivatives of an MRP system, being merely measured in rupees instead of physical units. For too long, financial systems have been driven by transactions and assumptions different from material control systems. The tools now exist to tie MRP and financial systems together by a simple conversion from physical units to rupees and vice versa. An MRP system can also be extended to support product costing and cost accounting. When an accurate BOM is in the computer, it is relatively a simple matter to calculate product costs from the labour and materials cost of the component parts. An MRP system can also be expanded into personnel planning by using a bill of labour. In this case all the labour skills for each product are listed on the bill of labour. The labour requirements are then exploded from the master production schedule in a similar way as material requirements. This makes it possible to forecast labour requirements and to tie together labour and material requirements.

## 2.5 Extended MRP Systems :

An MRP system should communicate information that is common to all the participants namely marketing, production, purchasing and financial departments. Hershauer and Eck [ 6 ]

suggested that the appropriate language for this purpose is financial in nature. This financial planning is the main feature of extended MRP system.

To efficiently and effectively support the corporate planning, the computer software for an extended MRP system be developed to satisfy the following criteria [ 6 ].

1. Rapid and easy system modification:

It should be expected that, over time, the firm will add new end items, discontinue other end items, change the product structure, modify production processes and so forth. At the time, when such changes are in the planning stage, system's software should be amenable to easy and rapid modification so as to show the implications of proposed changes.

2. Extensive what-if capabilities:

A lot of assumptions regarding the future demands for end items, lead items for purchasing and processing etc., enter the planning process of the MRP system. Hence, the system should be able to help the managers to determine how their plans will fare if the planned conditions change.

3. Easy and rapid report modification:

Over time, the information requirements of managers may change. Hence the system should be able to modify reports easily.

The various financial reports that can be generated by the system developed are:

1. Time-phased projections of the values of the inventories of purchased items, sub-assemblies and end products.

2. Time-phased projections of the purchased costs of

purchased items, assembly/manufacturing costs of sub-assemblies and end items.

3. Time-phased projections of anticipated revenue from the sale of end products and spare parts.

4. Summary reports of inventory values, expenses and revenues.

5. Projected funds flow summary.

## 2.6 System Replanning :

One of the requirements of an MRP system is that it must be a dynamic system and that it must adopt to change. By its very nature, MRP reflects the latest information in its planned order releases. In the updating procedures of the MRP, one period is added at the back end of the planning horizon and first period is taken off from the front end, and all of the periodic demands are again estimated. This updating is aimed at making the MRP system adaptive to changes in demands for the end items.

As the MPS is updated after every period the MRP schedules are also updated after every period. Another reason for updating MRP schedules after every period is to allow any changes in the inputs to MRP to be reflected in the schedules. Since the inventory status file, its material records, and the BOM file could have been changed since the last updating, the MRP schedules picks up these changes. For example, if engineering were to change the bills of material file to affect product design changes, after the next updating, the MRP schedule would reflect these changes.

There are two methods of replanning the MRP system. One of them is Net Change MRP system. This system updates the MPS as changes in it occur. The MRP system is then activated to generate a set of MRP outputs. These outputs, however, are only the net changes to past MRP runs and not an entire set of MRP outputs. The planned order schedule report, for example, would indicate only changes to previous planned order schedules, not a completely new schedule, although this concept is indeed tempting in theory, because it promises to serve as one big exception report that would greatly reduce the amount of information generated on each run, its incidence of application has been disappointing.

Many organizations continue to use the other method of replanning, called regenerative MRP. In this approach, a complete MRP run is processed periodically. At these times, a new MPS, an updated inventory status file, and an up-to-date BOM file are fed into the MRP system, which generates a complete set of outputs. Although, regenerative MRP systems are slightly more costly to prepare and process, they also apparently are easier to implement and manage.

## 2.7 Nervousness in MRP :

As discussed in section 2.3.7.11, Wagner-Whitin algorithm differs from many real world problems in two respects. First, this algorithm guarantees optimal ordering for each level of the hierarchy of product structure treated independently. But, as we know the BOM levels are not independent. Second problem is that the Wagner-Whitin model assumes that demand data remains

unchanged during the planning horizon. However, Baker [ 2 ] points out that most schedules are developed on a rolling basis whereby as each period passes, a new period is appended to the horizon. This can cause changes in all optimal lot sizes. A more serious effect occurs when a new and presumably more accurate data become available regarding future requirements. It is desirable to make use of these new data and rescheduling the lot sizes by applying the Wagner-Whitin algorithm, so as to ensure that scheduling decisions are based on the best data available. However, obtaining more accurate updated requirements can be mixed blessing. While new optimal schedules are produced, they can differ markedly from the previous schedule upon which some plans may already have been used. If, in the previous schedule, no setup is scheduled in a particular period plans concerning personnel scheduling and machine loading will be based on that expectation. If the schedule derived from the new data specifies a setup in that period, a great deal of difficulty may be encountered in changing those plans. This shifting of scheduled setup is called "nervousness" of the system.

Although the optimality of the solution provided by Wagner-Whitin algorithm is valuable, its price is too high-that price being the cost of changing plans. That is why many managers are preferring nonoptimal plans rather than the optimal plans that create nervousness. But it is not reasonable to avoid this nervousness at all costs. It is precisely the balance between the cost of nervousness and cost of nonoptimal solution that must be made in order to determine the amount of nervousness that is economically tolerable. Thus, if the cost of nervousness is

included in the model, this balance will be implicitly included in the resulting optimal solution.

Carlson et. al. [ 4 ] have formulated the above problem which takes into account the cost of nervousness so as to strike a balance between the cost of making schedule changes and the savings that such changes can effect. There are two forms of nervousness. In the first form, lot size change for periods in which setups are already scheduled. In the second form, new setups are scheduled in periods in which they were not scheduled.

Mather [ 7 ] has pointed out that the first form of nervousness will cost much less when compared to the second form. Hence Carlson et. al. have considered only the second form of nervousness. The cost of new setup, representing a change in schedule depends critically on the period for which it is scheduled. A new setup scheduled near the end of the planning horizon will have low cost, because a few commitments will be made based on scheduled plans for distantly future periods. On the otherhand, new setups scheduled for first few periods may be impossible to effect and thus can be considered to have an infinite cost. For the intermediate periods, any arbitrary cost function could be used.

The model proposed by Carlson et. al. is structurally identical to that of Wagner-Whitin. But Wagner-Whitin algorithm assumes that no schedule exists at the beginning of the planning horizon. This model assumes that a schedule exists and that the cost of schedule changes are included with setup costs and inventory holding costs in the total cost to be minimized.

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 |
| Planned order coverage | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 |

Table 2.1. Lot for Lot ordering.

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 60 | | | 60 | | | | | 60 |

Table 2.2 Fixed Order Quanitity ( 60 )

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 40 | 40 | | 40 | | | | | 40 |

Table 2.3 Minimum Order Quantity ( 40 )

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 58 | | | 58 | | | | 58 | |

Table 2.4 EOQ ( 58 )

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 60 | | | 45 | | |

Table 2.5 Modified EOQ

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 40 | | 25 | | 40 | |

Table 2.6 Fixed Period Requirements ( 2 periods)

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 85 | | | | | 65 | | | |

Table 2.7 Period Order Quantity ( 4 periods )

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 60 | | | 45 | | |

Table 2.8 Least Unit Cost

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 60 | | | 45 | | |

Table 2.5 Modified EOQ

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 40 | | 25 | | 40 | |

Table 2.6 Fixed Period Requirements ( 2 periods)

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 85 | | | | | 65 | | | |

Table 2.7 Period Order Quantity ( 4 periods )

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 45 | | | 60 | | | 45 | | |

Table 2.8 Least Unit Cost

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 5 | 10 | 30 |
| Planned order coverage | 85 | | | | | 65 | | | |

Table 2.9 Least Total Cost

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Net requirements | 35 | 10 | 0 | 40 | 0 | 20 | 55 | 10 | 30 |
| Planned order coverage | 45 | | | 40 | | 20 | 55 | 40 | |

Table 2.10 Modified LTC

# CHAPTER III

# SYSTEM IMPLEMENTATION DETAILS

## 3.1. Implemented Features :

An MRP system is developed in Turbo Pascal which includes the following features.

The system generates the net requirements for all the items in the product structure. Further it incorporates various lot sizing policies. These include:

Lot for Lot (LFL)

Fixed Order Quantity (FOQ)

Minimum Order Quantity (MOQ)

Economic Ordering Quantity (EOQ)

Modified EOQ

Fixed Period Requirements (FPR)

Period Order Quantity (POQ)

Least Unit Cost (LUC)

Least Total Cost (LTC)

Modified LTC

Wagner-Whitin algorithm was not implemented because of the reasons stated in section 2.3.7.11. In addition to the above lot sizing approaches, there is an option to optimize the lot sizing methods (treating each BOM level as independent). Planned order releases are computed by time phasing. Financial planning reports generation module is also incorporated in this system. This module generates the following reports.

1. Time-phased projections of the inventory values of purchased items, sub-assemblies and end products.

2. Time-phased projections of the cash requirements for the purchase of raw materials.

3. Time-phased projections of costs for assembly/assemblies, sub-assemblies and end products.

4. Time-phased projections of anticipated revenue from the sale of end products and spare parts.

5. Summary reports of future inventory values, expenses and revenues.

System replanning module is also implemented. Regenerative MRP method is used to replan the system. Using this module, one can advance the system by one period and regenerate the requirements and financial planning reports. There is a facility to edit the data before replanning the system, so as to make the system more upto date. The system flow chart is given in Figure 3.1. There are five modules in this system which are briefly described below.

1. **Input module:** This will take the input data from the user through the terminal. If the user wants to use an already created data file, the system will ask the file name and it reads into the system the data in that file.

2. **MRP processing module:** This contains the necessary logic (as explained in section 2.3) to process each item record to compute the net requirements and planned order releases.

3. **Rolling horizon module:** This module advances the system by one period and as such deletes the period 1 and appends one period to the end of the planning horizon. The user will be asked to input the data for the period to be appended. This module then

calls the MRP processing module to regenerate the requirements.

**4. Data editing module:** Using this module one can modify the data in the bill of materials, MPS, inventory status etc. This module will be run before the MRP processing and system replanning modules.

**5. Financial planning reports module:** This module generates the financial reports discussed in section 2.5. There is an option to store the reports in a text file.

## 3.2 Organization of Databases :

As stated before, the MRP system needs databases in the form of MPS, BOM and inventory status files. For easy programming and fast processing purposes, all the above files are merged together to form a master file. This file contains number of records; each record corresponding to an item in the product structure. The fields in each record are as follows:

Item code

Number of parents

Codes of the parents

Units of item required to make one unit of the paren

Price of the item

Setup cost

Inventory carrying cost

Manufacturing/assembly cost

On hand inventory

Safety stock

Allocated quantity

Lead time

Lot size policy

Characteristic of the lot size policy

Scheduled receipts

Gross requirements

Independent (spare part) demand

Net requirements

Planned order coverage

Planned order releases

The MPS is read into the gross requirements of the corresponding item. Further, the spare-part demand is read into the independent demand field for the appropriate items.

Apart from the above master file, another file is created to store the data regarding the planning horizon viz., the number of periods and the time-span of the planning horizon. This file carries the extension '.PHD' which means planning horizon data file.

The proposed MRP system has been implemented using Turbo Pascal Version 3.01A. The package will run on an IBM compatible monochrome/color PC. Options are available to view the MRP tables, financial reports etc. The user has an option to use an already created file. Further, the user can advance the system by one period and replan it; while doing so, he can modify the data in the product structure, item information etc. There is a facility to store the results in a text file. This file has '.RPT' as extension to its name.

## 3.3 Coding System :

The code (part number) of an item is a field of width 4

characters. The first character indicates the level at which the particular item is present in the product structure diagram. The top-most level (i.e. end items) is 'A', second level is 'B' and so on. The second and third characters in the code will identify that item among the other items present at the same level. The fourth character indicates whether the item is an end item, sub-assembly or a purchased material. The 4th character should be 'E' for an end item, 'S' for a sub-assembly, 'P' for a purchased item.

When the same item exists at different levels in the product structure (i.e. if the item has multiple parents at different levels) there will be recurrence of gross requirements. This problem is solved by employing the so-called low-level coding technique. The first character of the item should correspond to the lowest level at which the inventory item appears in the product structure. After the input is taken from the user, the records of the master file are sorted on the item code. Then the sequential processing on this sorted file will ensure the level-by-level process to run correctly.

A sample product structure is shown in Fig. 3.2 to illustrate the coding system.

## 3.4. Algorithm :

1. Read the input.

2. Process each record in the file sequentially using steps 3 through 6. If all the records are processed, go to step 7.

3. Compute the gross requirements as explained in section 2.3.1.

4. Compute the net requirements.

5. Obtain the planned order coverage using the selected lot sizing policy.

6. Time phase the planned orders to obtain the timing of the planned order releases.

7. Print the MRP tables and financial planning reports.

8. Replan the system, if the user wishes.

One can use the data file created previously and view the results or replan the system.

### 3.5 Limitations of the System :

The following are the limitations of the MRP system developed.

1. All the data in MPS , inventory status , spare part demand , and BOM (except the cost data ) is in integers only.

2. The data items specified as integers can not exceed the value 32767. This limitation is imposed by the programming language used ( Turbo Pascal Version 3.01A).

3. The modified MRP software developed in this work doesn't include capacity requirements planning ( CRP ) . The system assumes that sufficient capacity is available to carry out the master production schedule i.e. it assumes that the MPS is a feasible one .

4. Replanning frequency is restricted to one period only.

5. The proposed system can support a maximum of 26 BOM levels and a maximum of 17576 items.

An illustration demonstrating the use of the proposed modified MRP system is given in the next chapter.

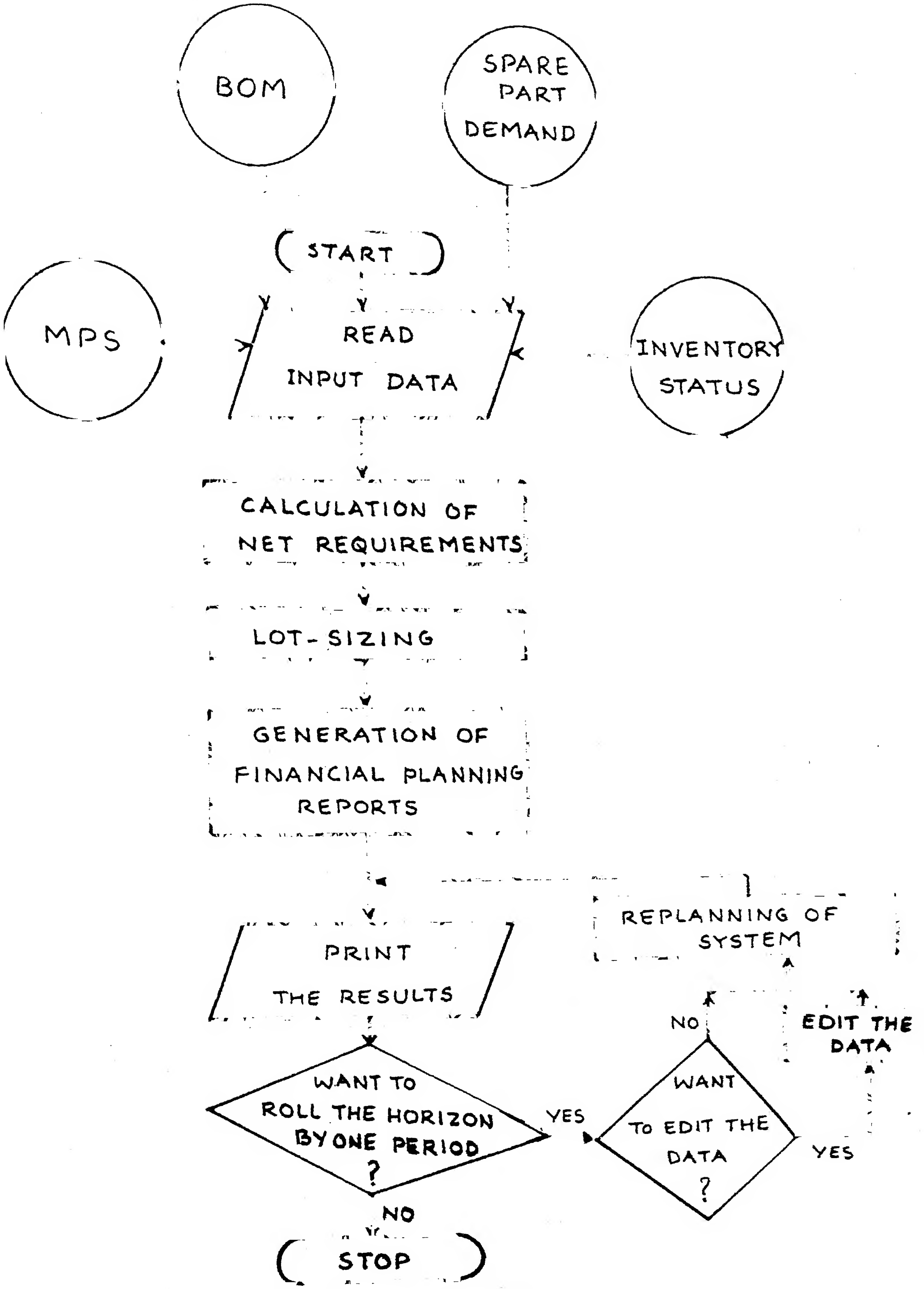


Figure 3.1. SYSTEM FLOW CHART

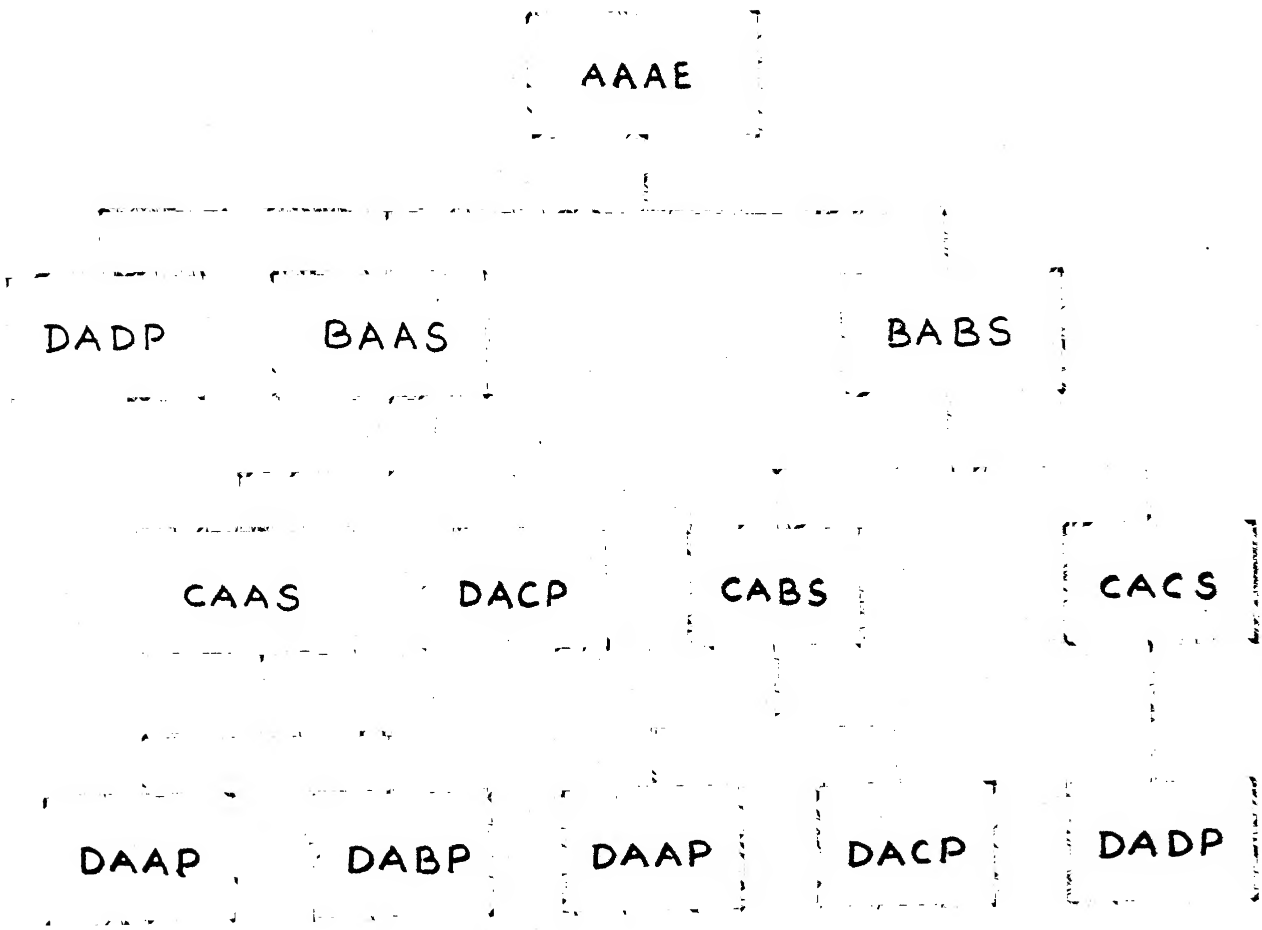


Figure 3.2. SAMPLE PRODUCT STRUCTURE TO ILLUSTRATE LOW-LEVEL CODING SYSTEM

# CHAPTER IV

# SAMPLE RESULTS & SCOPE FOR FURTHER WORK

## 4.1. Sample Results :

The system has been tested for a number of product structures. The results obtained from a sample problem are given below. The input data is as follows:

The product structure for the sample problem is given in Figure 4.1.

No. of periods in the planning horizon = 12

Time span the planning horizon covers = 1 Year

The master production schedule and the spare part demand are given in Tables 4.1 and 4.2, respectively. The input data for end items, sub-assemblies and purchased parts are shown in Tables 4.3, 4.4, and 4.5 respectively.

The outputs generated by the system for the above input are presented in Tables 4.6 to 4.27. Tables 4.6 to 4.12 show the MRP tables for each item. Table 4.13 shows the list of planned order releases. The cash requirements for all the purchased items are depicted in Tables 4.14 to 4.17. Assembly/manufacturing expenses for sub assemblies and end products are presented in Tables 4.18 and 4.19. Table 4.20 summarizes the cash requirements. Future projections of inventory values for purchased parts, sub-assemblies and end products are given in Tables 4.21 to 4.24. Further, the expected sales values from end products and spare parts are given in Tables 4.25 to 4.27.

## 4.2 Scope for Further Work :

This program can be extended to include capacity requirements planning ( CRP ), product pricing module, labour requirements planning. shop floor scheduling and control. There is a scope to implement the "nervousness" concept into the system.

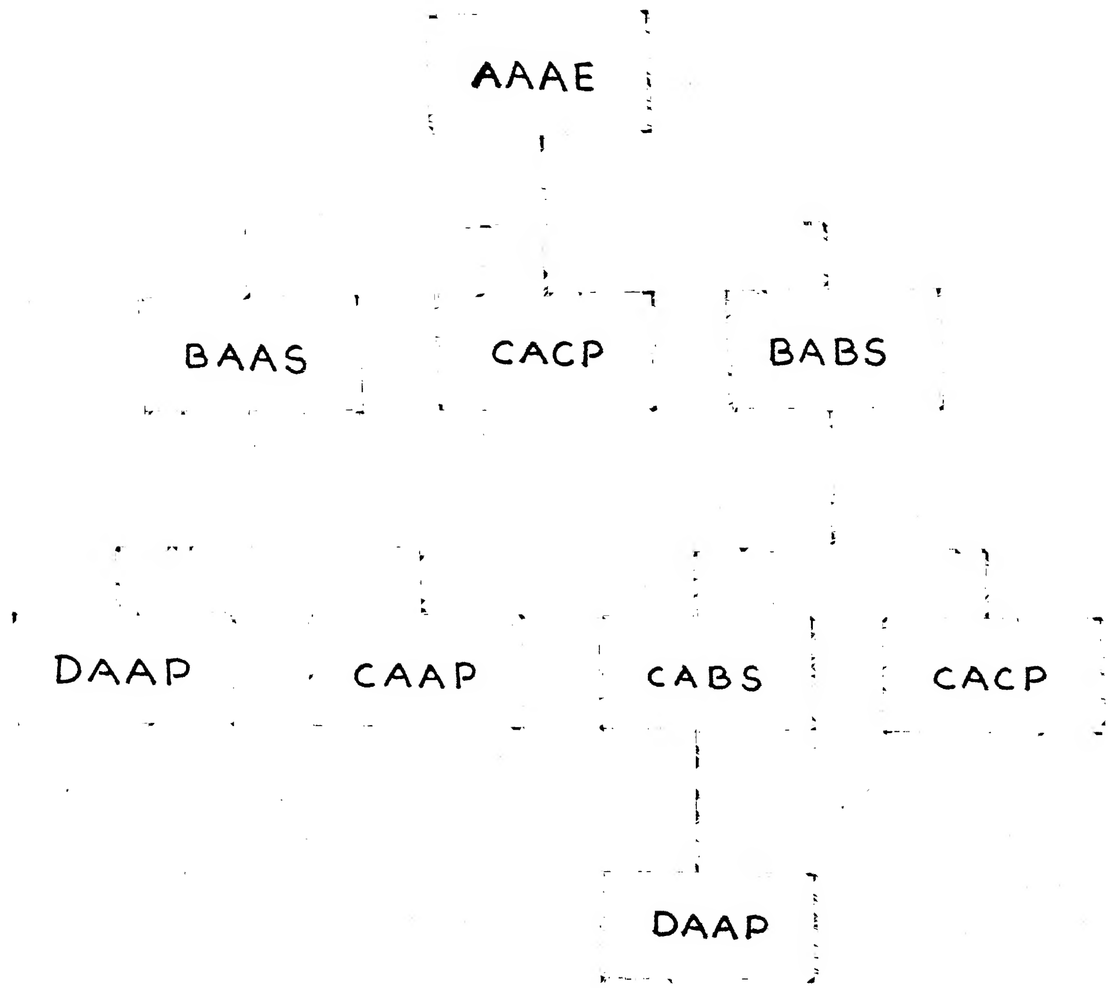


Figure 4.1 PRODUCT STRUCTURE FOR THE SAMPLE PROBLEM

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AAAE | 0 | 0 | 0 | 30 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 |

Table 4.1. Master Production Schedule

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BAAS | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 10 | 0 | 20 | 0 |
| BABS | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 |
| CABS | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 |

Table 4.2. Spare part demand

| Item: | AAAE |
| --- | --- |
| Lead time (periods) | 1 |
| Setup cost (Rs) | 200 |
| Carrying cost (Rs) | 2 |
| Assembly cost (Rs) | 15 |
| Sales price (Rs) | 500 |
| Stock at beginning (units) | 40 |
| Safety stock (units) | 15 |
| Quantity allocated (units) | 0 |
| Lot sizing policy | LFL |
| Scheduled receipts | Nil |

**Table 4.3. Data for end items**

| Item: | BAAS | BABS | CABS |
|---|---|---|---|
| Parent code and units of item reqd. for 1 unit of parent | AAAE, 1 | AAAE, 1 | BABS, 1 |
| Lead time (periods) | 1 | 1 | 1 |
| Setup cost (Rs) | 150 | 175 | 150 |
| Carrying cost(Rs/unit/period) | 1.75 | 2 | 1.25 |
| Assembly cost (Rs/unit) | 12 | 12 | 8 |
| Sales price as spare part(Rs) | 350 | 250 | 200 |
| Stock at beginning(units) | 40 | 50 | 30 |
| Safety stock (units) | 0 | 0 | 0 |
| Quantity allocated (units) | 0 | 40 | 0 |
| Lot sizing policy | FPR (2 periods) | LFL | EOQ |
| Scheduled receipts (units) | Nil | Nil | Nil |

**Table 4.4. Data for sub-assemblies**

| Item: | CACP | CAAP | DAAP |
|---|---|---|---|
| Parent code and units of item reqd. for 1 unit of parent | AAAE, 1<br>BABS, 1 | BAAS, 1 | BAAS, 1<br>CABS, 1 |
| Lead time (periods) | 1 | 1 | 1 |
| Setup cost (Rs) | 100 | 125 | 100 |
| Carrying cost(Rs/unit/period) | 1 | 1.5 | 1 |
| Purchase price (Rs/unit) | 50 | 60 | 60 |
| Stock at beginning(units) | 35 | 45 | 60 |
| Safety stock (units) | 0 | 0 | 0 |
| Quantity allocated (units) | 0 | 40 | 0 |
| Lot sizing policy | Optimal | FPR (2 periods) | LUC |
| Scheduled receipts (units) | 10 units in period 1 | Nil | Nil |

Table 4.5. Data for purchased items.

| | | | |
|---|---|---|---|
| Item code | :AAAE | Lead time | : 1 |
| Beginning inventory: | 40 | Safety stock: | 15 |
| Allocated : | 0 | Lot size | :Lot for Lot |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 0 | 30 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 0 | 5 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 |
| Plan Recpts: | 0 | 0 | 0 | 5 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 |
| Ending Inv.: | 25 | 25 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ord.Release: | 0 | 0 | 5 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 | 0 |

Table 4.6. MRP table for item AAAE

| | | | |
|---|---|---|---|
| Item code | :BAAS | Lead time | : 1 |
| Beginning inventory: | 40 | Safety stock: | 0 |
| Allocated : | 0 | Lot size | :Fixed Period Reqmts.( 2 periods) |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 5 | 45 | 0 | 30 | 5 | 35 | 10 | 40 | 40 | 0 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 0 | 10 | 0 | 30 | 5 | 35 | 10 | 40 | 40 | 0 |
| Plan Recpts: | 0 | 0 | 0 | 10 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 |
| Ending Inv.: | 40 | 40 | 35 | 0 | 0 | 5 | 0 | 10 | 0 | 40 | 0 | 0 |
| Ord.Release: | 0 | 0 | 10 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 |

Table 4.7 MRP table for item BAAS

| | | | |
|---|---|---|---|
| Item code | :BABS | Lead time | : 1 |
| Beginning inventory: | 50 | Safety stock: | 0 |
| Allocated : | 40 | Lot size | :Lot for Lot |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 5 | 60 | 0 | 25 | 5 | 50 | 0 | 40 | 20 | 0 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 0 | 55 | 0 | 25 | 5 | 50 | 0 | 40 | 20 | 0 |
| Plan Recpts: | 0 | 0 | 0 | 55 | 0 | 25 | 5 | 50 | 0 | 40 | 20 | 0 |
| Ending Inv.: | 10 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ord.Release: | 0 | 0 | 55 | 0 | 25 | 5 | 50 | 0 | 40 | 20 | 0 | 0 |

Table 4.8 MRP table for item BABS

| | | | |
|---|---|---|---|
| Item code | :CAAP | Lead time | : 1 |
| Beginning inventory: | 45 | Safety stock: | 0 |
| Allocated : | 40 | Lot size | :Fixed Period Reqmts.( 2 periods) |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 10 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 5 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 |
| Plan Recpts: | 0 | 0 | 5 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 |
| Ending Inv.: | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ord.Release: | 0 | 5 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 | 0 |

Table 4.9 MRP table for item CAAP

| | | | |
|---|---|---|---|
| Item code | :CABS | Lead time | : 1 |
| Beginning inventory: | 30 | Safety stock: | 0 |
| Allocated : | 0 | Lot size | :E O Q ( 67) |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 55 | 10 | 25 | 5 | 50 | 0 | 60 | 20 | 0 | 0 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 25 | 10 | 25 | 5 | 50 | 0 | 60 | 20 | 0 | 0 |
| Plan Recpts: | 0 | 0 | 67 | 0 | 0 | 0 | 67 | 0 | 67 | 0 | 0 | 0 |
| Ending Inv.: | 30 | 30 | 42 | 32 | 7 | 2 | 19 | 19 | 26 | 6 | 6 | 6 |
| Ord.Release: | 0 | 67 | 0 | 0 | 0 | 67 | 0 | 67 | 0 | 0 | 0 | 0 |

Table 4.10 MRP table for item CABS

| | | | |
|---|---|---|---|
| Item code | :CACP | Lead time | : 1 |
| Beginning inventory: | 35 | Safety stock: | 0 |
| Allocated : | 0 | Lot size | :Optimal lot size |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 0 | 60 | 45 | 25 | 30 | 55 | 35 | 40 | 60 | 20 | 0 |
| Sch.Recpts: | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 0 | 15 | 45 | 25 | 30 | 55 | 35 | 40 | 60 | 20 | 0 |
| Plan Recpts: | 0 | 0 | 85 | 0 | 0 | 85 | 0 | 75 | 0 | 80 | 0 | 0 |
| Ending Inv.: | 45 | 45 | 70 | 25 | 0 | 55 | 0 | 40 | 0 | 20 | 0 | 0 |
| Ord.Release: | 0 | 85 | 0 | 0 | 85 | 0 | 75 | 0 | 80 | 0 | 0 | 0 |

Table 4.11 MRP table for item CACP

| | | | |
|---|---|---|---|
| Item code | :DAAP | Lead time | : 1 |
| Beginning inventory: | 60 | Safety stock: | 0 |
| Allocated : | 0 | Lot size | :Least Unit Cost |

| Period: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross: | 0 | 67 | 10 | 0 | 35 | 67 | 45 | 67 | 80 | 0 | 0 | 0 |
| Sch.Recpts: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net: | 0 | 7 | 10 | 0 | 35 | 67 | 45 | 67 | 80 | 0 | 0 | 0 |
| Plan Recpts: | 0 | 119 | 0 | 0 | 0 | 0 | 112 | 0 | 80 | 0 | 0 | 0 |
| Ending Inv.: | 60 | 112 | 102 | 102 | 67 | 0 | 67 | 0 | 0 | 0 | 0 | 0 |
| Ord.Release: | 119 | 0 | 0 | 0 | 0 | 112 | 0 | 80 | 0 | 0 | 0 | 0 |

**Table 4.12 MRP table for item DAAP**

| Code | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AAAE | 0 | 0 | 5 | 45 | 0 | 25 | 5 | 35 | 0 | 40 | 20 | 0 |
| BAAS | 0 | 0 | 10 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 |
| BABS | 0 | 0 | 55 | 0 | 25 | 5 | 50 | 0 | 40 | 20 | 0 | 0 |
| CAAP | 0 | 5 | 0 | 35 | 0 | 45 | 0 | 80 | 0 | 0 | 0 | 0 |
| CABS | 0 | 67 | 0 | 0 | 0 | 67 | 0 | 67 | 0 | 0 | 0 | 0 |
| CACP | 0 | 85 | 0 | 0 | 85 | 0 | 75 | 0 | 80 | 0 | 0 | 0 |
| DAAP | 119 | 0 | 0 | 0 | 0 | 112 | 0 | 80 | 0 | 0 | 0 | 0 |

**Table 4.13 List of planned order releases**

| Period | Cash requirement |
|---|---|
| 1 | 0.00 |
| 2 | 425.00 |
| 3 | 0.00 |
| 4 | 2225.00 |
| 5 | 0.00 |
| 6 | 2825.00 |
| 7 | 0.00 |
| 8 | 4925.00 |
| 9 | 0.00 |
| 10 | 0.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.14 Cash requirements for purchases of item CAAP

| Period | Cash requirement |
|---|---|
| 1 | 0.00 |
| 2 | 4350.00 |
| 3 | 0.00 |
| 4 | 0.00 |
| 5 | 4350.00 |
| 6 | 0.00 |
| 7 | 3850.00 |
| 8 | 0.00 |
| 9 | 4100.00 |
| 10 | 0.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.15 Cash requirements for purchases of item CACP

| Period | Cash requirement |
|---|---|
| 1 | 7240.00 |
| 2 | 0.00 |
| 3 | 0.00 |
| 4 | 0.00 |
| 5 | 0.00 |
| 6 | 6820.00 |
| 7 | 0.00 |
| 8 | 4900.00 |
| 9 | 0.00 |
| 10 | 0.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.16 Cash requirements for purchases of item CAAP

| Period | Cash requirement |
|---|---|
| 1 | 7240.00 |
| 2 | 4775.00 |
| 3 | 0.00 |
| 4 | 2225.00 |
| 5 | 4350.00 |
| 6 | 9645.00 |
| 7 | 3850.00 |
| 8 | 9825.00 |
| 9 | 4100.00 |
| 10 | 0.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.17 SUMMARY OF CASH REQUIREMENTS FOR PURCHASED PARTS

| Period | Cash requirement |
|---|---|
| 1 | 0.00 |
| 2 | 686.00 |
| 3 | 1105.00 |
| 4 | 0.00 |
| 5 | 1045.00 |
| 6 | 921.00 |
| 7 | 1465.00 |
| 8 | 686.00 |
| 9 | 1765.00 |
| 10 | 415.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.18 SUMMARY OF MANUFACTURING EXPENSES FOR SUB-ASSEMBLIES

| Period | Cash requirement |
|---|---|
| 1 | 0.00 |
| 2 | 0.00 |
| 3 | 275.00 |
| 4 | 875.00 |
| 5 | 0.00 |
| 6 | 575.00 |
| 7 | 275.00 |
| 8 | 725.00 |
| 9 | 0.00 |
| 10 | 800.00 |
| 11 | 500.00 |
| 12 | 0.00 |

Table 4.19 SUMMARY OF MANUFACTURING EXPENSES FOR END-PRODUCTS

| Period | Purchases | Assembly/Mfg. Expenses | | Total |
|---|---|---|---|---|
| | | Sub-assemblies | End products | |
| 1 | 7240.00 | 0.00 | 0.00 | 7240.00 |
| 2 | 4775.00 | 686.00 | 0.00 | 5461.00 |
| 3 | 0.00 | 1105.00 | 275.00 | 1380.00 |
| 4 | 2225.00 | 0.00 | 875.00 | 3100.00 |
| 5 | 4350.00 | 1045.00 | 0.00 | 5395.00 |
| 6 | 9645.00 | 921.00 | 575.00 | 11141.00 |
| 7 | 3850.00 | 1465.00 | 275.00 | 5590.00 |
| 8 | 9825.00 | 686.00 | 725.00 | 11236.00 |
| 9 | 4100.00 | 1765.00 | 0.00 | 5865.00 |
| 10 | 0.00 | 415.00 | 800.00 | 1215.00 |
| 11 | 0.00 | 0.00 | 500.00 | 500.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 4.20** SUMMARY OF PURCHASE/MANUFACTURING/ASSEMBLY EXPENSES

| Period | Value of inventory |
|---|---|
| 1 | 6150.00 |
| 2 | 9270.00 |
| 3 | 9620.00 |
| 4 | 7370.00 |
| 5 | 4020.00 |
| 6 | 2750.00 |
| 7 | 4020.00 |
| 8 | 2000.00 |
| 9 | 0.00 |
| 10 | 1000.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.21 TOTAL INVENTORY VALUES OF PURCHASED PARTS

| Period | Value of inventory |
|---|---|
| 1 | 22500.00 |
| 2 | 22500.00 |
| 3 | 21900.00 |
| 4 | 6400.00 |
| 5 | 1400.00 |
| 6 | 2150.00 |
| 7 | 3800.00 |
| 8 | 7300.00 |
| 9 | 5200.00 |
| 10 | 15200.00 |
| 11 | 1200.00 |
| 12 | 1200.00 |

Table 4.22 TOTAL INVENTORY VALUES OF SUB-ASSEMBLIES

| Period | Value of inventory |
|---|---|
| 1 | 12500.00 |
| 2 | 12500.00 |
| 3 | 12500.00 |
| 4 | 0.00 |
| 5 | 0.00 |
| 6 | 0.00 |
| 7 | 0.00 |
| 8 | 0.00 |
| 9 | 0.00 |
| 10 | 0.00 |
| 11 | 0.00 |
| 12 | 0.00 |

Table 4.23 TOTAL INVENTORY VALUES OF END PRODUCTS

| Period | Inventory values of | | | Total |
|---|---|---|---|---|
| | Purchased Parts | Sub-Assemblies | End Products | |
| 1 | 6150.00 | 22500.00 | 12500.00 | 41150.00 |
| 2 | 9270.00 | 22500.00 | 12500.00 | 44270.00 |
| 3 | 9620.00 | 21900.00 | 12500.00 | 44020.00 |
| 4 | 7370.00 | 6400.00 | 0.00 | 13770.00 |
| 5 | 4020.00 | 1400.00 | 0.00 | 5420.00 |
| 6 | 2750.00 | 2150.00 | 0.00 | 4900.00 |
| 7 | 4020.00 | 3800.00 | 0.00 | 7820.00 |
| 8 | 2000.00 | 7300.00 | 0.00 | 9300.00 |
| 9 | 0.00 | 5200.00 | 0.00 | 5200.00 |
| 10 | 1000.00 | 15200.00 | 0.00 | 16200.00 |
| 11 | 0.00 | 1200.00 | 0.00 | 1200.00 |
| 12 | 0.00 | 1200.00 | 0.00 | 1200.00 |

**Table 4.24** SUMMARY OF INVENTORY VALUES OF ALL THE ITEMS

| Period | Sales value |
|---|---|
| 1 | 0.00 |
| 2 | 0.00 |
| 3 | 0.00 |
| 4 | 5750.00 |
| 5 | 0.00 |
| 6 | 1750.00 |
| 7 | 0.00 |
| 8 | 3750.00 |
| 9 | 7500.00 |
| 10 | 0.00 |
| 11 | 7000.00 |
| 12 | 0.00 |

Table 4.25 TOTAL SPARE PART SALES VALUE OF SUB-ASSEMBLIES

| Period | Sales value |
|---|---|
| 1 | 0.00 |
| 2 | 0.00 |
| 3 | 0.00 |
| 4 | 15000.00 |
| 5 | 22500.00 |
| 6 | 0.00 |
| 7 | 12500.00 |
| 8 | 2500.00 |
| 9 | 17500.00 |
| 10 | 0.00 |
| 11 | 20000.00 |
| 12 | 10000.00 |

Table 4.26 TOTAL SALES VALUE OF END PRODUCTS

| Period | Sales values of | | Total |
|---|---|---|---|
| | Sub-Assemblies | End Products | |
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 |
| 4 | 5750.00 | 15000.00 | 20750.00 |
| 5 | 0.00 | 22500.00 | 22500.00 |
| 6 | 1750.00 | 0.00 | 1750.00 |
| 7 | 0.00 | 12500.00 | 12500.00 |
| 8 | 3750.00 | 2500.00 | 6250.00 |
| 9 | 7500.00 | 17500.00 | 25000.00 |
| 10 | 0.00 | 0.00 | 0.00 |
| 11 | 7000.00 | 20000.00 | 27000.00 |
| 12 | 0.00 | 10000.00 | 10000.00 |

Table 4.27 SUMMARY OF SALES VALUES OF SPARE-PARTS AND END PRODUCTS

CHAPTER V

USER MANUAL

## 5.1 System Files :

The MRP system is implemented in Turbo Pascal version 3.01A. The source code is available in the files MRP.PAS and PART.INC. The compiled version is in the following files :

MRP.COM

MRP.000

MRP.001

MRP.002

MRP.003

MRP.004

MRP.005

MRP.006

MRP.007

This system is completely menu-driven. One has to use the arrow keys to move cursor over the options and press return to select.

## 5.2. How to Use the System ? :

To run the system give the command:

MRP <CR>

This will bring the file creation/set-up menu (see Figure 5.1) on to the screen. There will be two options in the menu. The option

"Create a new file"

lets you create a new data file (new product structure). The other option

"Use already created file"

lets you use an already created data file.

If you select the first option, the system will ask the user to input the data regarding the BOM, MPS, planing horizon etc. There an option to edit/modify the data during/after inputting. The edit menu is given in Figure 5.2.

There are four options in this menu. The first one lets you delete an item from all its parent i.e. to withdraw an item from manufacturing process. Second option lets you to withdraw an item going into a particular parent . With the third option, one can add an item to product structure. The fourth option can be used to modify the data of the item (i.e. lead time, safety stock, demand, lot-size etc.). The menu for modifying the data of an item is given in Figure 5.3.

After inputting and editing is over, the system calculates the requirements. Then next menu will come, in which there will be two options (see Figure 5.4). With first option, one can view/store the results. The menu for this option is given in Figure 5.5. In this menu there are options to view MRP tables, list of planned order releases, cash requirements for the purchase of items, assembly/manufacturing costs of sub-assemblies and end products, summary reports of cash requirements, inventory values of purchased parts,sub-assemblies and end products, and summary reports of inventory values. There is an option to store all these reports in a text file. This file will have the extension ".OUT" in the file name.

The second option in the menu of Figure 5.4 lets you

advance the system by one period and replan the requirements. There is an option to edit the data before the replanning.

The system stores the inventory status data in a file. The file name (without extension) is to be given by the user. The created file with same filename, but having extension ".PHD", to store the data regarding the planning horizon (i.e. number of periods in the planning horizon and the length of time-period the planning horizon spans).

## 5.3. Precautions :

Care should be taken to enter the data correctly. For example, the coding system explained in section 3.4. has to be followed strictly. If the code is entered incorrectly the results will not come as expected. All the data expect the cost data and item codes should be integers only. If the data is wrong, the results are also going to be incorrect. Sufficient options are provided to modify/edit the data wherever possible.

FILE SET-UP MENU

CREATE A NEW FILE

USE ALREADY CREATED FILE

QUIT

Use arrow keys to move over options
Press [RETURN] to select option

Figure 5.1 FILE SET-UP MENU

EDIT MENU

DELETE AN ITEM FROM ALL ITS PARENTS

DELETE AN ITEM FROM A PARTICULAR PARENT

ADD AN ITEM TO THE PRODUCT STRUCTURE

MODIFY THE DATA OF A PARTICULAR ITEM

QUIT

Use arrow keys to move over options
Press [RETURN] to select option

FIGURE 5.2 EDIT MENU

MODIFY MENU

CHANGE THE LEAD TIME
CHANGE THE LOT SIZE TECHNIQUE
CHANGE THE SET-UP/ORDERING COST
CHANGE THE INVENTORY CARRYING COST
CHANGE THE ASSEMBLY/Mfg. COST PER UNIT
CHANGE THE PRICE OF THE ITEM
CHANGE THE ON-HAND AMOUNT
CHANGE THE SAFETY STOCK
CHANGE THE ALLOCATED AMOUNT
CHANGE THE SPARE-PART DEMAND/MPS
CHANGE THE SCHEDULED RECEIPTS
CHANGE THE QUANTITY OF THIS ITEM GOING INTO ITS PARENT
--> QUIT

Use arrow keys to move over options
Press [RETURN] to select option

Figure 5.3 MENU TO MODIFY THE DATA OF AN ITEM.

RESULTS/ADVANCE MENU

VIEW/STORE THE RESULTS

ADVANCE THE SYSTEM BY ONE PERIOD

QUIT

Use arrow keys to move over options
Press [RETURN] to select option

Figure 5.4 MENU TO VIEW THE RESULTS AND TO ROLL THE HORIZON

```
                              REPORTS MENU

          VIEW THE MRP TABLES
          LIST OF PLANNED RELEASES
          PROJECTED CASH REQUIREMENTS FOR PURCHASED PARTS
          PROJECTED MANUFACTURING EXPENSES FOR SUB-ASSEMBLIES
          PROJECTED MANUFACTURING EXPENSES FOR END PRODUCTS
          SUMMARY REPORT OF PROJECTED EXPENSES
          PROJECTED INVENTORY VALUES OF PURCHASED PARTS
          PROJECTED INVENTORY VALUES OF SUB-ASSEMBLIES
          PROJECTED INVENTORY VALUES OF END PRODUCTS
          SUMMARY REPORT OF PROJECTED INVENTORY VALUES
          PROJECTED SALES REVENUE FROM SPARE PARTS
          PROJECTED SALES REVENUE FROM END PRODUCTS
          SUMMARY REPORT OF SALES REVENUE
          STORE THE RESULTS IN A FILE
      --> QUIT

                  Use arrow keys to move over options
                   Press [RETURN] to select option
```

Figure 5.5 MENU TO VIEW THE RESULTS

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